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TABLE OF CONTENTS, FIGURES, TABLES, AND FORMULA

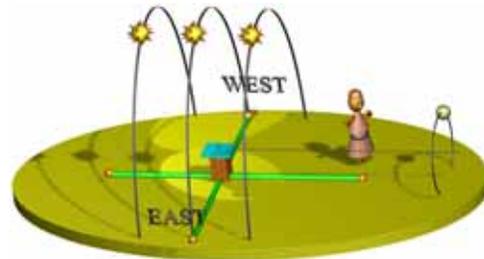
Introduction

some old dials in England where the author was born and grew up
some portable dials made between 1800 and 1960
A Quick Hands On Project

PART ONE

Chapter 1

The approximate evolution of the dial
1.1 early altitude dial
1.2 early azimuth dial



Chapter 2

How the earth does its thing
The earth going around the sun, the tilted polar axis and equator
Or is it the sun going around the earth
Solstice and equinox ~ every day on the equator is an equinox
Latitude (up down) and longitude (left right) to define location on earth
Latitude and longitude in Arizona and New Mexico
2.1 the earth orbits the sun
2.2 the sun orbits the earth in a manner of speaking
2.3 summer solstice
2.4 latitude references
2.5 longitude references
2.6 maps and latitude and longitude and the sun's movement
2.7 hoe the equation of time (EOT) is derived
2.8 some key dates for the EOT (equation of time)

Chapter 3

How the sun does its thing
Apparent time is what the sun shows on a sun dial
Legal time is the official time on a special line of longitude for a time zone
Longitude correction enables legal to time to come from apparent time
Mean solar time is a pretend time of a perfect constant sun
And apparent time to legal time still needs a correction based on the date
The correction based on date is called the equation of time (EOT)
The equation of time shown as a monthly variation
When do you add the EOT and when do you reverse its signs
The sun in the winter, summer and at the equinoxes
More about longitude time corrections ~ four minutes per degree
More on why days vary in length and it is always equinox on the equator
North and south hemisphere differences in the context of sun dials
3.1 the EOT as a figure of eight, an analemma
3.2 the sun's motion in the sky for an observer
3.3 the observed solar sighting from two different places
3.4-6 summer and winter solstices and the equinox and day length
3.7 altitude, azimuth, and solar hour angle differences



Chapter 4

Determining true north
You can use a survey map ~ but beware!
A magnetic compass is quick but you need to correct it and not be near iron
You can spend a day and see the sun cross an arc morning and afternoon
You can calculate the time of noon or any other hour considering the EOT and longitude
You can use an astro-compass
You can use a flat sheet of wood and a nail, and compare actual and calculated azimuths
You can use the stars at night
4.1 measuring a wall's alignment (declination)
4.2 using a compass
4.3-4 the sun's daily movement shows true north
4.5 the EOT throughout the year
4.6 the night sky in the northern hemisphere

Chapter 5

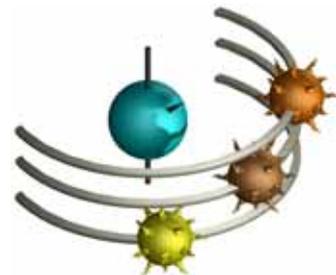
- The armillary dial with 15 degree hour lines
- The equatorial dial with 15 degree hour lines
- The polar dial whose hour lines increase in distance is introduced
- How a sundial is constructed and some key points
- The dial plate and gnomon
- The nodus, style, and dial center
- Dial furniture ~ declination lines can be used for many things
- My vertical wall dial and one of my horizontal dials
- 5.1 dial nomenclature
- 5.2-3 actual horizontal and vertical dials.
- 5.4-5 shadows
- 5.6 the armillary dial construction
- 5.7 the sun observed from two differing locations
- 5.8 an actual armillary dial
- 5.9 armillary dial construction measurements
- 5.10 equatorial dial design
- 5.11-12 polar dial generic layout

Chapter 6

- The polar dial in more detail
- Methods of building dials,
- Empirical methods, the trigon using the equatorial dial as a projection
- Geometrical methods based on the empirical concepts
- Trigonometric methods based on the geometrical concepts
- The empirical method in more detail on a polar dial
- The geometrical method in more detail on a polar dial and with longitude correction demonstrated and with solstice, equinox or other lines of declination
- The trigonometric method in more detail on a polar dial
- 6.1 a trigon for empirical methods
- 6.2 some key dates for the EOT (equation of time)
- 6.3-4 polar dial construction pictorials
- 6.5 empirical polar dial technique
- 6.6-7 polar dial with and without longitude correction
- 6.8-9 polar dial calendar or declination line geometric construction
- 6.10-11 polar dial calendar or declination line trigonometric construction
- 6.12 CAD layout for a polar dial

Chapter 7

- A vertical dial facing true east or west
- Called a meridian dial as their dial plate lies in the meridian
- Geometrical method
- With and without longitude correction
- With declination lines to show the seasons
- Trigonometric method
- With declination lines
- And with the proof of the trigonometric formula
- 7.1-4 meridian (true east or west facing dials)
- 7.5 meridian dial calendar lines depicted
- 7.6-7 meridian dial layout with and without longitude correction
- 7.8-9 meridian dial calendar lines of declination
- 7.10-11 meridian dial trigonometric methods
- 7.12 proof of trigonometric formula for meridian dial



Chapter 8

- A horizontal dial
- The empirical method revisited for the horizontal dial
- Including longitude correction
- And if you have a wide gnomon, where are the hour lines before 6am and after 6pm based on
- Declination lines using a trigon
- The geometric method for a horizontal dial
- Longitude correction
- Drawing hour lines more than three hours from noon ~ two methods
- Declination lines using geometry
- Another geometrical method for a horizontal dial
- Trigonometric methods for the horizontal dial
- Declination lines using trigonometry
- 8.1 a trigon for empirical methods
- 8.2 a horizontal dial and its pieces to build an hour line
- 8.3 longitude correction and the horizontal dial

- 8.4 where hour lines start on a horizontal dial with a thick gnomon
- 8.5 using a trigon for calendar lines on a horizontal dial
- 8.6 a geometric method for a horizontal dial
- 8.7-8 two techniques for hours far from noon
- 8.9 a different geometric method for a horizontal dial
- 8.10 a geometric method for calendar lines on a horizontal dial
- 8.11 trigonometric method for a horizontal dial
- 8.12 method for calendar lines using the sun's altitude for a horizontal dial

Chapter 9

- A vertical dial facing south, and facing north also.
- It is the same as for a horizontal dial built for the co-latitude
- Introduction to hour line tables using spreadsheets
- Proof that horizontal and vertical dials share a co-latitude relationship
- Relevant thought for vertical reclining dials, discussed later.
- The vertical dial facing north ~ the gnomon points upwards
- 9.1 hour angle tables for a horizontal or a vertical dial
- 9.2 how a vertical dial has an associated horizontal dial at its co-latitude
- 9.3-4 a vertical dial facing north

Chapter 10

- A general geometric model of the dials discussed so far
- By now many normal dial building methods have been discussed
- Is there a common architecture
- 10.1-2 a general model of the dials discussed to date
- 10.3 every weird dial has a simple doppelganger somewhere else in the world
- How the sixteenth century concept comes alive with CAD

Chapter 11

- A vertical recliner
- Cases where the roof's pitch is the same as the latitude.
- Cases where the roof's pitch is the less than the latitude.
- Cases where the roof's pitch is the more than the latitude.
- 11.1 vertical recliner whose slope equals latitude
- 11.2 vertical recliner whose slope is less than latitude
- 11.3 vertical recliner whose slope is more than latitude
- 11.4 an amusing corollary



PART TWO

Chapter 12

- A vertical decliner (mostly south facing)
- An overview of how the method is used and why it works
- The geometric method on one page
- Introducing the concept for vertical decliners of twisting the gnomon
- A trigonometric method for twisting the gnomon
- A vertical decliner (predominantly east or west facing)
- Introducing the "great decliner" tables for managing sloping lines, such as an equinox line.
- Great decliners
- 12.1-2 a vertical and horizontal symbiotic dial and its use for vertical declining dials
- 12.3-4 the first of two geometric methods, intuitive but does not help with calendar lines
- 12.5 the second geometric method, a bit less intuitive, but facilitates calendar lines design also.
- 12.6-8 the second method's generation of a "style height", SH, for the rotated gnomon.
- 12.9 the second method's generation of the rotation angular measurement, "style distance", SD.
- 12.10-11 reviewing the rotated gnomon for the second geometric method
- 12.12 adding hour lines using the second method
- 12.13-14 trigonometric method for rotating the gnomon

Chapter 13

- A vertical declining recliner
- The geometry of a reclining surface such as a roof
- Together with a declining wall such as a building not aligned with the true cardinal points.
- The geometrical methodology is shown, from which can be derived the empirical methods.
- No trigonometric method is shown as there are so many variables.
- 13.1-4 vertical declining decliners

Chapter 14

- The great decliner
- What they are
- Terminology

A general concept about dials not aligned conveniently

The gnomon design process – using trigonometry

The equatorial line

The hour lines

- 14.1-3 gnomons for dials that decline a lot
- 14.4 terminology for declining dials
- 14.5 how declining dials related in all four quadrants
- 14.6 great decliner tables can be used
- 14.7 use of CAD (computer aided design) for a great decliner – dial center not accessible
- 14.8 taking the non accessible dial center hour angle lines to a usable dial plate
- 14.9 using a spreadsheet to help find hour line coordinates

Chapter 15

Other types of sun dials

altitude dials ~ which use solar altitude, not hour angle

capuchin dial

shepherd's dials

the O-G dial

a horizontal altitude dial

azimuth dials:

a wing shaped azimuth dial with a fixed gnomon

analemmatic dials (these have no hour lines, only hour points,

and a vertical gnomon whose base moves with the date)

other hour angle dials:

ceiling dials (these use hour angle)

moon dials (these use hour angle)

globe dials

cube dials

15.1-4 capuchin dial design

15.5-6 actual capuchin dial

15.7-8 shepherd's dial design

15.9 actual shepherd's dial

15.10 CAD design of shepherd's dial

15.11 O-G or ogee dial drafted with CAD

15.12-13 a horizontal altitude dial

15.14-15 a horizontal azimuth dial design

15.16 actual horizontal azimuth dial in use

15.17-18 analemmatic dial design of the ellipse and hour and calendar points

15.19-20 analemmatic dial tables to simplify the trigonometry

15.21 CAD layout of an analemmatic dial

15.22 actual analemmatic dial in use

15.23 azimuth tables for an azimuth dial that will be vertical

15.24 CAD layout for a vertical azimuth dial

15.25 actual vertical azimuth dial in use

15.26-27 globe dials, and to variations on them

15.28 layout of a bi-filar dial

15.29 actual bi-filar dial in use

15.30-31 self orienting dials

Chapter 16

Declination lines encapsulated

16.1 calendar or declination lines on an armillary dial

16.2-3 calendar lines on an equatorial dial

16.4 polar dial calendar lines

16.5 horizontal dial calendar lines

16.6 vertical decliner equinox calendar line layout

16.7 vertical decliner using a horizontal dial for it's

calendar lines

Chapter 17

Extra things

Safety tips

Shadow definitions

Errors in sun dialing

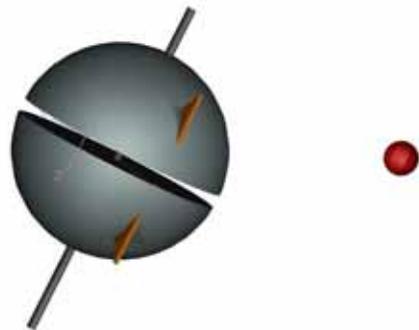
Some figures of the universe and solar system

Solstice and equinox lines and day duration lines

Babylonian hours and Italian lines (hours to sunset)

Length of day lines

Dial mottoes



Some 3D pictures of sun dials
 A paper cutout sundial
 Reverse engineering store bought generic dials
 Important dates for the dialist
 A few sundials of interest
 17.1 shadows form
 17.2 shadow sharpness
 17.3 Italian hour lines
 17-- some collectibles
 17-- some 3d pictures

Extra things

Chapter 18

The use of cad, or computer aided design, and vrmf on the web
 2d drawing
 3d object modeling
 The use of spreadsheet programs
 converting formulae used in math to
 formulae usable in a spreadsheet
 using graph functions for altitude curves and hour lines
 The use of older methods
 The Middleton Scales
 Building a legal standard time dial – and taking a year to do it

Chapter 19

The use of stained glass for a sun dial

PART THREE

Appendix 1

Trigonometric functions and geometrical rules and circular measures
 Tables of trig values – sin, cos, and tan
 figure a.1 trigonometry terms
 a1.2-3 geometry terms
 tables a1.1 trigonometry values 0 through 90 degrees



Appendix 2

Tables independent of location
 The equation of time, and 5 day values, and averages, and more
 Sun's apparent hour angle
 Longitude to time
 Julian day
 Polar and Meridian dial tables
 Declination of the sun by the day
 equation of time EOT table for all the days of a generic year, and longitude adjustments for EOT
 a2.1 and a two sine wave set of tables
 a2.1b c and a three sine wave set of tables
 a2.1d e
 a2.2 sun's apparent hour angle and associated trigonometric values
 a2.3 degrees of longitude to hours and minutes of time
 a2.4 Julian days of the typical year
 a2.5 city location data with associated figures
 a2.6 time zones
 a2.7 chart for easterly magnetic variation (declination)
 a2.8 chart for westerly magnetic variation (declination)
 a2.9 easy to use magnetic to true bearing chart
 a2.10 polar and meridian dial hour line distances every 15 minutes
 a2.10a polar and meridian dial hour line and declination distances
 a2.11 typical solar declination by the day for a typical year (may differ from other tables just a bit)
 a2.12 equatorial dial calendar line radii and sunrise/set horizontal line distance relative to gnomon size

Appendix 3

Tables for horizontal and vertical dial hour line angles
 Hour line angles for horizontal and vertical dials latitude 30 to 60
 a3.1a-c horizontal and vertical dial hour angles for latitudes 30 through 60

Appendix 4

Tables for sun declination and hourly altitude - considers latitude
Tables for sun declination and hourly azimuth - considers latitude
Table for analemmatic dials – angle to hour point, and analemma
a4.1a-j solar altitude by the hour for latitudes 30-60
a4.2a-j solar azimuth by the hour for latitudes 30-60
a4.3 analemmatic hour points for latitudes 30 through 60 with gnomon distances

Appendix 5

South facing decliner hour angles and gnomon adjustment
Tables for the great decliner (vertical), east/west gnomon adjustment
a5.1a-j vertical decliners, declination +/- 45 degrees, latitudes 30-60, with SD, SH, DL & AV values
a5.2a-j vertical decliners, declination +/- 45-85 degrees, latitudes 30-60, SD, SH, DL, AV values

Appendix 6

Sunrises and sunsets for some longitudes and latitudes.
Ways of finding sunrise and sunset.
a6.3 sunrise and sunset for a latitude corrected for longitude and EOT, a few locations.
a6.4 sunrise, set, day-length for most latitudes in true solar [local apparent time]
used for Italian, Babylonian, and Day-length data for dial plates.

Appendix 7

Miscellaneous proofs, and oddities
Proof that the sun is at 90 degrees to the style on the equinox.
Proof that $\cotan(\text{angle}) = \text{defined as } \tan(90-\text{angle}) = 1/\tan(\text{angle})$
Proof that a vertical dial design is the same as a horizontal design for the co-latitude
Proof of SD (style distance) and SH (style height) formulae for decliners and great decliners
Proof of altitude and azimuth measuring on a wall plate device
The Southern Hemisphere – Australia and the like
Interesting trivia for the dinner table

Appendix 8

Collection of formulae
Spreadsheet implementations of tables in these appendices
a8.1-2 sun's declination and day angle intermediate figure
a8.3 sun's altitude
a8.4 sun's azimuth
a8.5-6 sunset and sunrise
a7 equatorial dial calendar arc radius, and sunrise/set horizontal line distance from gnomon
a8.8 horizontal dial hour angle
a8.9-10 polar dial hour line and calendar declination formula
a8.11-12 meridian (east or west) hour line and calendar declination formula
a8.13 south vertical non decliner hour angle hour lines
a8.14 analemmatic ellipse minor axis formula
a8.15-16 analemmatic hour point horizontal and vertical coordinates
a8.17 analemmatic hour point angle from ellipse center in place of using a8.15-16
a8.18 analemmatic gnomon displacement formula
a8.19-20 EOT to standard time formula
a8.21-24 vertical decliner table, hour line angles, SH and SD (style height and distance)
difference in longitude formula (it and SH show where a vertical decliner is horizontal)
a8.25-26 obsolete
a8.27 bi-filer east west wire linear height
a8.28 bi-filer east west wire displacement linear distance from dial center
a8.29a equation of time approximations (two wave)
a8.29b equation of time approximations (three wave)
a8.29c equation of time approximations (seven wave)
a8.30 a work sheet for horizontal dials
a8.31 a work sheet for vertical (decliners or non decliners)
a8.32 a drafting sheet for horizontal/vertical dial declination or calendar lines
a8.33 a drafting sheet for vertical declining dial production of style distance and height.

Appendix 9

Templates for dial design
paper cutout dials for fun (see also chapter 19 for a paper cutout 3-d popup dial)

Appendix 10 Books, software, and cross references to them

Supplements Additional material of relevance